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(1)

ARMY Declass/Release Instructions On File

SURVEY REQUIREMENTS FOR GUIDED MISSILE SYSTEMS

1. The over-all accuracy of a missile system depends upon many supporting elements, two of which are surveying and mapping. A study by the Army Map Service of survey requirements for guided missiles has been aimed at determining: (1) the surveying and mapping operations required, (2) the techniques which should be standard for troops engaged in surveying, and (3) the new instruments which should be developed for missile support.

2. There are two types of survey requirements; "basic" and "immediate."

a. Basic requirements are defined as those which will be met by a long-range coordinated program. Such requirements can be satisfied by a knowledge of the areas within approximately 50 miles of the targets and the missile launching sites and should be accomplished before the advent of hostilities.

b. Immediate requirements are defined as those which can normally be met on short notice, but which cannot be accomplished until the precise launcher and target locations are designated.

3. Two basic requirements apply to all missiles:

a. There is a requirement for topographic maps of an accuracy within a specified scaling error since maps provide the principal method of obtaining target location and also provide a secondary method of obtaining launcher location.

b. There is a requirement for a network of control points adjusted to a geodetic datum. The relative value of the control network is usually expressed as number of control points per 100 square

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miles or 100 square kilometers. The control points within this network provide the primary means of obtaining launcher orientation and position. The adjusted control point network is preferable to either astronomic means for obtaining launcher orientation or to using maps for obtaining the launcher position.

c. Two additional basic requirements apply to only certain type of missiles:

(1) There may be a requirement for the connection of various geodetic datums.

(2) There may be a requirement for a description of the gravity field including average anomalies, deflections of the vertical, and so forth.

3. Three immediate requirements apply to all missiles:

a. There is a requirement for an orienting azimuth.

b. There is a requirement for the position and elevation of the launcher.

c. There is a requirement for the position and elevation of the target.

d. Two additional immediate requirements apply to only certain types of missiles:

(1) There may be a requirement for a base line to facilitate a tracking device, and/or

(2) There may be a requirement for a description of the gravity field and deflection of the vertical at the launcher to facilitate an inertial guidance system.

e. Immediate requirements have been divided into two standards

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or accuracy: (1) "optimum" standard, and (2) "minimum" standard.

(1) The optimum standard of accuracy will be obtained by survey specifications which can be met, in an area where the basic requirements have already been accomplished, by standard troop survey techniques. These can be met without extraordinary effort or delay affecting the tactical effectiveness of the missile. In areas of reasonably dense control and adequate maps the optimum standard is normal. In some cases, it will provide an accuracy much better than necessary for a specific system; but, as with any survey operation, the surveyors' work should be maintained at a certain level of precision as a matter of good habit. Also, the survey may be put to more stringent uses for unanticipated purposes.

(2) The minimum standard of accuracy is defined as that resulting from those survey specifications necessary to give a 50% assurance that the total effect of all surveying and mapping errors is not more than one-third the CEP of the missile. Thus, in effect, the minimum standard of accuracy is the poorest survey result we can produce without its becoming a question of concern to the tactical commander using the missile. In areas where basic requirements have been met, we should never be reduced to the minimum, but in areas where the basic requirements are lacking we may often be unable to meet even the minimum accuracy standard with present techniques - particularly at the target end.

5. Included in this subject is the matter of target location, which is not normally considered a part of the survey requirements. However, inasmuch as an error in target location has exactly the same effect as an equal error in launcher location, it is impractical to consider one while ignoring the other.

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6. While a distinction is made between "optimum" and "interim" only for the immediate requirements in this study, it is evident that all basic requirements should be met in an optimum manner. Priority, rather than standard accuracy, is the problem in achieving the basic requirements.

7. A summary of "basic" and "immediate" requirements together with tabulations is attached as enclosure 1. This enclosure describes estimates of the requirements which should be established for various types of missiles.

a. An examination of one particular case; a 200-mile range inertial-guided ballistic missile with a CEP on the order of 300 meters, shows that the basic requirement for 90% of map features to be accurate within 50 meters requires a Class A 1:100,000-scale map. A larger scale map would be superior for meeting this basic requirement due to the fact that the plotting accuracy is increased. However, if only a 1:200,000-scale map is available features would be accurate only to within 100 meters. This 100 meters would use up all of the minimum one-third of the 300-meter CEP allowed for survey purposes. The datum connection requirement of 30 meters is one that can easily be met by any connection within 200 miles, such as across a strait or between national systems. The control point density of four per 100 square miles assures that we should never have to go more than six or seven miles to obtain control for orientation. The gravity requirements are negligible; the in-flight effect of gravity anomalies is on the order of centimeters for a ballistic missile of this range.

b. The picture would change considerably, however, for a longer-range, slower, aerodynamic missile, which may travel 30 times as far at one-sixth the velocity of the missile used as an example. Due to the

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longer-range missile's lower velocity, gravity anomalies along the flight path would have sufficient effect to require the application of correction factors.

c. The optimum immediate requirements would be compatible with standard survey techniques, although the determination of an astronomic azimuth would be advisable if the orientation were brought in by transverse more than a few miles from second-order or better control.

d. The minimum immediate requirements are largely taken up by target location. In the unlikely situation of a good target location coupled with spasmodic control in the launcher area, more latitude could be allowed in azimuth and launcher position.

6. The terms of probability theory, such as "90% assurance" are used in this study. Such terms are appropriate while studying the problem and establishing the requirements. However, in determining the methods by which these requirements are to be met, it is more important to think in terms of reliability instead of probability. Guided missiles do not require extraordinary accuracy by survey standards, but their expense and limited number make reliability paramount in the design and function of their supporting systems, including surveying and mapping. It is necessary that the trig lists--the delivered form of the basic survey data--are free from mistakes and out-of-date references. Troop survey procedures should be expressed in hard-and-fast terms of instruments, methods of observation, number or repetitions, rejection rules, cross checks, and so forth.

9. The principal area in which unsatisfied basic requirements exist is that of maps for target location. Density of control also needs to

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be improved in many parts of the world in which present control is insufficient to ensure tactical flexibility in the launching of missiles.

10. To meet the immediate requirements, a swift, all-weather method of obtaining an orienting azimuth is needed. Aerial flares suffice can rapidly bridge considerable distances, but are limited to favorable weather. Gyroscopic devices are the best means now foreseen for obtaining an all-weather azimuth. These can also be used as a valuable double-check on azimuths obtained by conventional means.

11. The study of survey requirements discloses three basic tasks which must be accomplished:

a. An over-all goal must be established. This would include determination of the accuracy which must be delivered to missile systems. This task can be approached by the distinction we have made between "optimum" and "minimum" requirements.

b. The specific parts of the survey task which should be included in the "basic" and the "immediate" requirements must be determined.

c. Having made the distinction between basic and immediate, there is the third task of determining the assignment for accomplishing the accuracy requirements among the various survey and mapping elements so that they can be met by an effort that is reasonable under the likely circumstances. Related to this third task is the matter of building the maximum reliability into our survey procedures, whether by standard methods or improved instruments and techniques.

Enclosure: Summary and Tabulations

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SURVEY REQUIREMENTS FOR GUIDED MISSILE SYSTEMS
BASIC AND IMMEDIATE REQUIREMENTS, SURVEY AND MAPPING

1. Definitions

a. Basic Requirement: A surveying and mapping requirement which normally required a long-range coordinated program to meet, but which can be met knowing only the general areas (e.g., within 50 miles) of targets and missile launching sites. Types of basic requirements are:

(1) Topographic maps of an accuracy within a specified scaling error, usually expressed as a 90% assurance in meters.

(2) Connection of geodetic datums, usually expressed as standard error in meters.

(3) A network of control points all with positions referred to a geodetic datum and with geodetic azimuths to other points, usually expressed as a density of points per 100 square miles.

(4) A description of the gravity field, expressed as standard error for the average anomaly, deflection of the vertical and geoid height of a specified size of area or length of line.

b. Immediate Requirement: A surveying requirement which normally can be met on short notice, but which cannot be performed until the precise launching (or guidance station) position and target are designated. Immediate requirements are divided into two orders:

(1) Optimum: That which can be met, in an area where the basic requirements have been fulfilled, by standard troop survey methods without extraordinary effort or delay affecting the tactical effectiveness of the missile.

(2) Minimum: That which is necessary to give a 90% assurance that the total effect of all survey and mapping errors is not more than one-third the CEP of the missile.

(3) Types of immediate requirements are:

(a) Orienting azimuth, expressed as 90% assurance in seconds of arc.

(b) Launcher (or guidance station) horizontal position, expressed as 90% assurance in meters.

(c) Target horizontal position, expressed as 90% assurance in meters.

(d) Baseline, expressed as length and 90% assurance proportionate error.

(e) Launcher elevation expressed as 90% assurance in meters.

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(c) Target elevation expressed as 90% assurance in meters.

(d) Launch point gravity, expressed as 90% assurance in milligals.

(e) Launch point deflection of the vertical, expressed as 90% assurance in seconds of arc.

2. Basic Requirements

Missile Type	Missile Range (Miles)	Map Accuracy 90% Assurance (meters)	Control Density (points per 100 square miles)	Datum Connection (standard deviation, meters	Gravity Field
Ballistic	50	25	4	----	None
Ballistic	75	25	4	----	None
Ballistic	200	50	4	30	None
Aerodynamic	500	100	4	30	None
Ballistic	1500	150	4	50	None
Ballistic	5000	400	1	200	(only indirect, for Earth figure)
Aerodynamic	500	400	1	200	Deflection of the vertical, 5° square means -2.00"

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3. Immediate Requirements:

a. Optimum:

Missile Type	Missile Range (Miles)	Azimuth 90% Assurance (seconds)	Launcher Position 90% Assurance (meters)	Launcher Elevation 90% Assurance (meters)	Baseline 90% Assurance Proportionate error	Launcher Gravity 90% assurance (mgals.)	Launcher Deflection of the Vertical 90% Assurance (seconds)
Ballistic	20	60	10	10	None	None	None
Ballistic	75	30	10	10	?	None	None
Ballistic	200	15	10	10	None	10	30
Aerodynamic	500	15	10	50	1:15,000	10	30
Ballistic	1500	5	10	50	None	5	10
Ballistic	5000	2	10	50	?	2	4
Aerodynamic	5000	2	10	50	None	2	4

NOTE: Optimum target location would be determined from a topographic map.

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b. Minimum:

Missile Type	Missile Range	Missile CEP (meters)	Azimuth 90% Assurance (seconds)	Launcher 90% Assurance (meters) Position	Launcher 90% Assurance (meters) Elevation	Baseline 90% Assurance Proportionate Error	Launcher Gravity 90% Assurance (mgals.)	Launcher Deflection of the Vertical 90% Assurance (seconds)	Target 90% Assurance (meters) Position	Target 90% Assurance (meters) Elevation
Ballistic	20	200	180	40	100	None	None	None	100	100
Ballistic	75	300	60	40	100	?	None	None	200	50
Ballistic	200	300	30	40	100	None	None	45	200	900
Aerodynamic	500	1000	30	100	200	1:15,000	None	45	600	1000
Ballistic	1500	3000	30	300	200	None	10	45	2000	1000
Ballistic	5000	7500	30	1000	200	?	10	45	4500	1000
Aerodynamic	5000	7500	30	1000	200	None	10	45	4500	1000

NOTE: Minimum target location would be determined from an aerial sensing system or a sub-standard map.

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GENERAL SURVEY REQUIREMENTS FOR MISSILES

"BASIC"
(PRE-HOSTILITIES)

ALL MISSILES

Topographic Maps

Control Network

CERTAIN MISSILES

Datum Connections

Gravity Data

"IMMEDIATE"
(DURING HOSTILITIES)

ALL MISSILES

Orienting Azimuth

Launch Point Position and Elevation

CERTAIN MISSILES

Base Line

Launch Point Gravity and Deflection of the Vertical

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GEODETIC REQUIREMENTS

200 - MILE BALLISTIC MISSILE

90% ASSURANCE

	"BASIC" (PRE-HOSTILITIES)	"EMERGENCY" (DURING HOSTILITIES)	
		Optimum	Minimum
Launcher Position		10 meters	40 meters
Launcher Elevation		10 meters	100 meters
Target Position		50 meters	800 meters
Target Elevation		10 meters	500 meters
Azimuth		15 seconds	30 seconds
Base Line		None	None
Launch Point Gravity		10 mgal.	None
Launch Point Deflection of the Vertical		30 seconds	45 seconds
Map -- 50 meters			
Datum Connection -- 30 meters			
Control Density -- 4 Points per 100 square miles			
Gravity Field -- None			

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SECRET

(2)

EXCERPTS FROM:

BRIEFING PRESENTED TO ARMA
By Lt Col D. E. Woodyard
Assistant Commanding Officer
Army Map Service

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INTRODUCTION

As Colonel Miller pointed out, I will discuss three principal functional fields; namely, geodesy, mapping, and targetting. Geodesy is important to the application of missiles in that it provides the framework for tying together features on the earth's surface thousands of miles distant. It is this same framework on which maps are constructed. The maps extend the geodetic coverage by providing the location of features which fall on and between the network of geodetic control. The targetting effort analyses and selects those features which are critical for a coordinated application of missiles.

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MAPPING

It appears certain to us in mapping that one of the most significant ways of locating targets for missiles will be by direct measurement on large scale maps. Thus, maps will be used extensively.

When we entered World War II we had practically no maps of foreign areas. Throughout the war we relied on our allies, primarily the British, to supply basic map sources in combat areas. (PAGE 20)

Since War II we have been engaged in a relatively intensive map collection program.

Graphic I portrays the Army Mapping Requirements Col. Miller mentioned previously that these requirements are being reviewed at the present time and that AMSA has been asked to submit its recommendations for changes. These requirements were generated by top-level war planning. They may be considered the long-range Army Mapping program. They serve as the goal for efforts in map collection and geodetic control and aerial photography operations. Incidentally we do not ignore the blank areas in map collection.

Graphic II shows our present map holdings. These holdings are divided into five degrees of accuracy with definite measurements in feet.(PAGE 21)

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The red areas show large scale maps on which detail may be located within 80 feet. We call these maps Class A. We have precious few of these precise maps in the USSR.

The orange areas indicate large scale maps scalable within 81 to 160 feet. We call them Class B. Such maps on the Iron Curtain countries are scattered.

Both dark green and light green indicate maps which are scalable within 161 to 800 feet. These maps we call Class C. The dark green indicated large scale maps scalable with a probable accuracy of 400 feet. (PAUSE 22)

The light green differentiates the medium scale maps falling in the same accuracy range. Their scalable accuracy tends toward the 800 foot limitation.

Medium scale maps which have an accuracy within 801 to 1500 feet are shown in light blue. We call this Class B. Large portions of USSR, southern Asia and the Far East fall into this category.

The blank areas are those for which no large or medium scale maps are available to us. Notice the large gaps in the coverage of USSR.

I would discuss briefly a graphic of our current mapping program. We use six years as a planning cycle. We revise the immediate phases of the program annually. (PAUSE 23)

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Now we return to our Existing Coverage Graphic IX. The blank areas on the graphic require, generally, the collection of map sources, geodetic control, and aerial photography to publish a map of suitable accuracy. Maps alone could provide this result. (PAGE 24)

We also have the problem of increasing the accuracy of these Class B, C, and especially D areas. Additional map sources, geodetic control and aerial photography are needed.

Accomplishing new, systematic, geodetic control and photographic operations for the Sino-Soviet is impossible. Map procurement in these areas is extremely difficult and precarious. We do possess much of their pre-war mapping. We attempt to utilize this data to the maximum.

In areas accessible to us, we are conducting aerial photographic operations and securing or assisting in geodetic control operations. (PAGE 25)

We recognize many deficiencies in our current map holdings, we are, by cooperative arrangements with many countries, reducing or eliminating these deficiencies. (PAGE 26) We are engaged in continuous, intensive map and mapping materials collection through every channel and by every device available to us. (PAGE 27)

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GEODESY FOR GUIDED MISSILES

In considering the significance of geodetic control in guided missile operations, we find it convenient to think of the launching of these weapons as another form of artillery fire. The system of guidance control may be described as an electronic gun-barrel. That this gun barrel might well be two hundred miles long does not change the basic problems, it merely introduces a change in scale. This change in scale emphasizes the need for an accurate, homogeneous, worldwide system of reference for all military geodesy and mapping, a system that will accurately relate the target to the gun no matter where each is located. (PAGE 3)

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IMPORTANCE OF GEODETIC DATA IN MISSILE GUIDANCE

The significance of geodetic control for the guidance of missiles of various ranges can be considered under three heads: Launching, Mid-course Guidance, and Terminal Guidance. It is also necessary to distinguish in each of these cases between the requirements of the pilotless bombers and the requirements of the ballistic missile.

At the time of launching a ballistic missile requires a relatively inaccurate determination of its own position, and a relatively precise determination of orientation. The positional accuracy need not be more accurate than the determination of the target position since both determinations will enter with equal weight in the final error. (PAGE 4)

It would require an unusual combination of circumstances to produce [priority] anomalies so large as to cause serious deviations from course for ballistic missiles; on the other hand, with the very best available geodetic material it appears that for the pilotless bomber discrepancies of 600 to 800 ft can be anticipated in ordinary areas and major deviations in troubled areas. It is for this reason that information on the undulations of the geoid, especially in Eurasia, is of such significance in the operation of slow traveling missiles.

In short, slow travelling missiles are greatly affected by the variations of gravity; the ballistic type missiles are not greatly affected and, in areas where they are most likely

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to be used, the geodetic problem in their guidance is largely one of accurately relating the target to the launching site. (PAGE 5)

To aid in presenting a picture of the worldwide geodetic situation and a report of our progress on our program we have prepared a set of graphics.

On graphic IV are shown the principal systems of horizontal control throughout the world. These systems provide the framework around which all of our geodetic operations are built. You will note that there are important areas of deficiencies in this framework and also that transoceanic connections are yet lacking. Our planning for future operations is basically for the correction of these deficiencies.

Graphic V shows our holdings of detailed control. (PAGE 7)

The density of the control is significant in guided missile operations for two reasons. First the greater the density of control the less survey is required for accurately positioning the launching and guidance sites. Secondly, existing dense control nearly always indicates that the mapping of the area is well controlled and target positions scaled from the maps will be accurate. For positioning the launching sites the three degrees of density shown on this graphic could well be labelled - Excellent - little field survey required, - Good - several hours of survey required, and - Poor - datum uncertain or extensive surveys required. The last item is continually being improved under our program. (PAGE 8)

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As I mentioned earlier we plan to improve the world geodetic situation by field measurements that supplement and interconnect the primary networks shown on our first graphic. These measurements will provide us with connections that will permit the reduction to a single datum over the greater part of the earth. They will also provide much needed data for the determination of the figure of the earth. The legend on graphic VI is a bit complicated and I will describe it in some detail. The blue represents planned connections by MIRAN trilateration only; electronic trilateration by [redacted] or other electronic means are shown in orange. Trilateration is a means of extending control by electronic measurement. Conventional triangulation is dark red, when both triangulation and precise leveling are planned the combination is symbolized in pink. The light green symbol shows locations where ground elevations will be determined by some airborne electronic (PAGE 12) means such as the airborne profile recorder. The purple dashes and stars indicate the planned measurements across Pacific ocean areas by star occultations. (PAGE 13)

We are hoping that the planned artificial satellite may prove to be a useful tool in solving many of the geodetic problems. If it can be successfully observed optically we can acquire a great amount of useful highly accurate geodetic (PAGE 14)

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e. Determination of its position by electronic measure-

ments appear quite feasible and could provide us with much

useful information.

We have given our opinion that gravity data is not

of primary importance in the guidance of intermediate range

ballistic missiles. However, it is of great importance for

intercontinental missiles of any type. A knowledge of the

gravity field over the North Atlantic is particularly important.

The black double circles indicate our belief that the Navy

should give high priority to its submarine gravity measurement

program in that area. (PAGE 15)

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SUMMARY:

In closing I would like to comment on the reliability problem as it applies to missile guidance. We have talked in terms of CEP accuracies of 1500 feet. Obviously if we expect to obtain an accuracy of 1500 ft CEP, we cannot rest content with individual errors in our geodetic data of 1500 ft. (PAGE 18) In the first place, mathematically, a 1500 ft CEP implies a standard deviation not more than 800 ft in each coordinate. In the second place, the concept of reliability developed by Mr. Robert Lauzer, here at Redstone Arsenal, proposes that there shall be a margin of 11 standard deviations between the performance of a component and the over-all requirement of the missile. In this case, the over-all requirement is in the neighborhood of 1500 ft CEP; hence, the geodetic component should have an error not exceeding about 150 ft CEP, or perhaps 50 ft in each coordinate.

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